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BMJ Open

The correlation of sarcopenia and depressive mood in elderly Chinese community dwellers

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-038089
Article Type:	Original research
Date Submitted by the Author:	27-Feb-2020
Complete List of Authors:	chen, lei; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital tang, tingting; the First People's Hospital of Yancheng, Department of Geratology sheng, yunlu; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital qi, hanmei; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital lv, shan; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital,
Keywords:	Depression & mood disorders < PSYCHIATRY, GERIATRIC MEDICINE, Old age psychiatry < PSYCHIATRY

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The correlation of sarcopenia and depressive mood in elderly Chinese community dwellers

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Funding

This study was funded by a grant from the National Natural Science Foundation of China (81871096) to Shan Lv.

Word count: 2595

Tables: 2

Figures: 4

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Abstract

Objective: Whether sarcopenia is detrimental to depression is still controversial, which may be due to the three components of the sarcopenia. Our objective was to define the correlation between depression and sarcopenia in elderly Chinese community dwellers.

Design: The study has a cross-sectional design.

Setting: The study was conducted in Jiangsu, China.

Participants: A total of 101 men and 149 women aged 60 years or older were recruited.

Outcome measures: Lean tissue mass was measured by dual-energy X-ray absorptiometry. Muscle strength in the upper and lower limbs was measured by a handheld dynamometer and a chair stand test, respectively. Physical performance was assessed by gait speed and standing balance test. Depressive mood was assessed using the Geriatric Depression Scale-30 (range 0–30).

Results: Subjects in the sarcopenia group had a higher mean depression score than the no-sarcopenia group. Pearson's correlation analysis showed that depression was negatively associated with muscle strength and physical performance, especially in female subjects. Multiple linear regression models revealed that depressive mood was inversely associated with chair stand test, gait speed and standing balance test scores after adjusting for confounding factors, while no significant correlation was observed between depressive mood and muscle mass. Moreover, physical performance was negatively associated with levels of blood glucose, but not lipids.

Conclusion: The diagnostic components of sarcopenia—strength of leg muscles (Chair Stand Test) and physical performance (gait speed and standing balance test)—were associated with depressive mood.

Keywords: Muscle mass, Muscle strength, Physical performance, Depression, Elderly

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Strengths and limitations of this study

- Our findings highlight the significance of muscle strength and function but not muscle mass in relation to depression in elderly Chinese community dwellers.
- The chair-stand test, also called the chair-rise test is used as a proxy for strength of leg muscles (quadriceps muscle group) according to the European Working Group on Sarcopenia in Older People (EWGSOP2).
- The study also measures the relationship between the components of sarcopenia and some clinical variables such as fasting levels of glucose, cholesterol, triglycerides, low-density lipoprotein and high-density lipoprotein.
- It would have been improved if we had acquired data on activity levels and dietary habits.
- A cross-sectional study cannot establish a causal relationship between depressive mood and sarcopenia.

Introduction

Depression is characterized by significant and lasting sadness, and is the most common type of mood disorder. Clinically, it is observed that a patient's level of depression can range from extreme grief to feelings of inferiority, pessimism and world-weariness, and serious suicidal behavior[1]. It is generally accepted that depression is a leading cause of disability worldwide and a major contributor to the overall global burden of disease[2]. An article published in 2017 on the official website of the World Health Organization (WHO) reported that 322 million people suffered from depression worldwide, and that the number of patients increased by 18.4% between 2005 and 2015. China is the country with the largest number of people suffering from depressive disorders, with a prevalence of 4.2%[3]. However, Iceland has the highest use of

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antidepressant drugs, which are generally ignored by Chinese patients[4]. Therefore, although there are effective drug treatments for depression, it is particularly important to look for risk factors associated with early depression.

Skeletal muscle comprises about 40% of total body mass in a healthy-weight individual. Ageing is associated with body composition changes, such as increased visceral fat and reduced muscle mass[5]. Sarcopenia is defined as the loss of muscle mass, muscle strength and decreased physical performance due to aging[6]. Previous studies have investigated the relationship between sarcopenia and depressive mood[7]. For example, a cross-sectional sample of a longitudinal cohort from the Ansan Geriatric (AGE) Study reported that depression in elderly Koreans was associated with low body mass and sarcopenia, especially in men[8]. In addition, a statistically significant relationship was observed between sarcopenia and depression in older male patients with diabetes[9]. A recent study involving Japanese urban-dwelling older adults revealed that depressive mood was not associated with decreased muscle mass, but was associated with low muscle strength and low physical performance[10]. In contrast, results from the 2010–2011 Korean National Health and Nutrition Examination Survey showed that sarcopenia was not associated with depression in Korean adults[11]. Therefore, the exact relationship between depressive mood and components of sarcopenia is still unknown.

In this study, we chose healthy community dwellers aged 60 years or older who did not suffer from diseases that might affect muscle metabolism. Our aim was to explore the correlation between depressive mood and the diagnostic components of sarcopenia in elderly Chinese community dwellers.

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Materials and methods

Study participants

The study subjects were selected from elder community dwellers who participated in the annual health screening program at Huaqiao Road Community Health Service Center in Jiangsu, China. The inclusion criterion was being aged 60 years or older. Subjects were excluded if they had diseases that might affect muscle metabolism such as inflammatory myopathy, Parkinson's disease, stroke, myocardial infarction, significant liver disease, creatinine clearance of <30 ml/min or cancer. The mental status of the study subjects was assessed by the mini-mental status examination (MMSE) and subjects with cognitive impairment were excluded. Subjects who failed to go through the assessment of sarcopenia were also excluded. Finally, 101 men and 149 women were recruited for the study.

Height and weight were measured by standard methods with subjects wearing light clothing without shoes. Body mass index (BMI) was calculated as BMI (kg/m^2) = Weight (kg)/height^2 (m^2).

Ethical and legal considerations

The clinical study was approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University, Jiangsu, China, in accordance with the Declaration of Helsinki. The participants themselves gave their Written informed consent to participate in the study and were informed that they could refuse to participate at any stage.

Muscle mass, muscle strength and physical performance assessment

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A dual-energy X-ray absorptiometry (DXA) scanner (Hologic Inc., Bedford, MA, USA) was used to measure appendicular skeletal muscle mass (ASM). As absolute muscle mass correlates with height, the appendicular skeletal muscle mass index (SMI) was calculated as SMI (kg/m^2) = ASM (kg)/height^2 (m^2). All scans were obtained by one certified technician. The instruments used in this study exhibited stable long-term performance [coefficient of variation (CV) < 0.5%] and satisfactory in vivo precision.

The grip strength of each subject's dominant hand was measured three times with a hand dynamometer (Jamar®, Los Angeles, CA, USA). Three attempts separated by a 1-min interval were recorded, and the maximum value (in kg) was taken for further analysis. The chair-stand test, also called the chair-rise test, can be used as a proxy for strength of leg muscles (quadriceps muscle group) and measures the length of time required for a patient to rise five times from a seated position without using his or her arms.

Physical performance was assessed by the walking speed, standing balance[12]. For the walking speed test, participants were asked to walk along a straight walkway on a flat floor at their usual speed. Walking speed was measured over the 4 m distance between markers placed at 3 m and 7 m from the start of the walkway, and the mean walking speed (m/s) was calculated. For the standing balance test, subjects were asked to stand in three positions, using arms or other means to maintain balance, but could not move the foot.

Short Physical Performance Battery (SPPB), comprising measurements of walking speed, standing balance, and the chair-stand test. The individual test score is 4 and the total SPPB score is 12.

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Depression Assessment

The severity of depressive mood was evaluated using the 30-item Geriatric Depression Scale (GDS-30) developed by Brank et al. in 1982. The GDS-30 was rater-administered in a standardized manner with the interviewer questioning the subjects and recording their responses to the individual items.

All items in the GDS-30 are rated as 0 or 1; specifically, 1 = "No" and 0 = "Yes" for some items (1, 5, 7, 9, 15, 19, 21, 27, 29, 30) but 0 = "Yes" and 1 = "No" for the remaining items. Item scores are summed, resulting in a possible total score of 0–30. High scores represent more severe depression.

Diagnosis of Sarcopenia

According to the European Working Group on Sarcopenia in Older People (EWGSOP)[13], sarcopenia was defined according to muscle mass, muscle strength, and physical performance. Pre-sarcopenia is determined by low muscle mass with preserved muscle strength and normal physical performance. Sarcopenia is defined as low muscle mass plus either diminished muscle strength or physical performance, and severe sarcopenia is defined as the co-occurrence of all three factors.

Low muscle mass was defined as an SMI below 7.26 kg/m^2 (male) and 5.5 kg/m^2 (female). Low muscle strength was defined as handgrip strength < 30 kg for men and < 20 kg for women. Low physical performance was defined as an SPPB score ≤ 8.

Statistical analysis

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Descriptive data are presented as mean ± standard deviation (SD) or median (first to third quartile). The associations between depression score and muscle mass, muscle strength, and physical performance were examined using Pearson's correlation analysis. Multiple linear regression models were used to analyze SMI, handgrip strength, chair-stand test, gait speed, and SPPB, using age, sex, BMI, glucose, triglyceride (TG), total cholesterol (TC), high- and low-density lipoprotein-cholesterol (HDL-C and LDL-C) data. All statistical analyses were performed using SPSS version 20.0 (IBM Corp, Armonk, NY, USA), and $p < 0.05$ was considered statistically significant.

Patient and public involvement

No patient was involved in developing the research question, outcome measurement and design of the study. We are unable to disseminate the findings of the research directly to the study participants.

Results

General characteristics, muscle mass, muscle strength and function and depressive mood of participants

Table 1 shows participants' background characteristics. The analysis included data from 250 elderly Chinese community dwellers, of whom 149 were men (mean age: 69.82 ± 6.84 years) and 101 were women (mean age: 67.69 ± 6.20 years). The mean GDS-30 score in the male and female groups was 4.43 ± 3.53 and 4.62 ± 4.11 points, respectively. The mean relative muscle mass (SMI) was 7.10 ± 0.79 kg/m^2 for males and 5.63 ± 0.72

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kg/m^2 for females. We evaluated the strength of the upper and lower limbs by handgrip strength (38.86 ± 7.89 kg for male, 24.48 ± 4.38 kg for female) and the chair stand test (9.18 ± 3.18s for male, 9.47 ± 5.56 s for female), respectively. The assessment of physical performance involved measuring gait speed, a standing balance test, and an SPPB score.

Correlation between depressive mood and muscle mass, muscle strength, and physical performance

We carried out a Pearson correlation analysis of the above data, and found that depression scores correlated significantly with muscle strength in both sexes, in terms of handgrip strength (R = -0.196, p = 0.048 for males, R = -0.170, p = 0.028 for females) and chair stand test performance (R = 0.311, p = 0.001 for males, R = 0.252, p = 0.002 for females) (Fig 2). Moreover, as shown in Fig 3, in females, depression was negatively associated with physical performance measured by gait speed (R = -0.200, p = 0.009), standing balance test performance (R = -0.224, p = 0.006), and SPPB score (R = -0.218, p = 0.007). However, in males there was a negative correlation between depressive mood and an SPPB score (R = -0.252, p = 0.010) but not with gait speed or standing-balance test performance. In contrast, no significant correlation was observed between muscle mass and depressive mood in either males or females (Fig. 1).

Multiple regression analysis of depressive mood, muscle mass, muscle strength, and physical function

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Given the significant independent relationships between age, sex, BMI, glucose, lipid metabolism, and parameters of sarcopenia, we performed multiple linear regression analyses. In our multiple linear regression models (Table 2), depressive mood was inversely associated with chair-stand test performance, gait speed, standing balance-test performance and SPPB, while no significant correlation was found between depressive mood and muscle mass.

Interestingly, the level of glucose was negatively associated with physical function ($\beta = -0.034$, $p = 0.012$ for gait speed, $\beta = -0.153$, $p = 0.008$ for the SPPB, $\beta = -0.083$, $p = 0.005$ for the standing balance test), whereas lipid metabolism was not associated with any parameters of sarcopenia.

Depression scores in different stages of sarcopenia

We further analyzed the depression scores of subjects exhibiting different stages of sarcopenia, such as pre-sarcopenia and sarcopenia. Following the EWGSOP definition, the numbers of subjects in normal, pre-sarcopenia, and sarcopenia groups were 118, 91 and 40, respectively. As expected, subjects' depression scores gradually increased with the extent of muscle loss. Subjects with sarcopenia had higher depression scores than the normal group ($p = 0.035$), while there was no significant difference between the depression scores of the pre-sarcopenia and the sarcopenia group (Fig. 4).

Discussion

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Compared with other psychiatric patients, depressive patients exhibit poor compliance with medication. Specifically, studies have found that 50% to 60% of patients stopped taking medication for 10–16 weeks, and that only 22% of depressive patients received regular medication[4 14]. Depressive symptoms are aggravated and recur in patients who are unable to comply with treatment. Thus, early detection of depression-related risk factors and early intervention are particularly important in the context of a single course of antidepressant treatment in the face of poor patient compliance.

Our data showed an association between depressive mood and sarcopenia in adults aged 60 and over. This was consistent with the results of a meta-analysis, whose authors concluded that patients with sarcopenia were likely to present with depression[15]. Furthermore, we found that depressive mood was negatively associated with strength of leg muscles and physical performance measured by gait speed, standing balance, and SPPB score, even after adjusting for confounding factors. However, no significant correlation was observed between muscle mass and depressive mood in either males or females.

The definition of sarcopenia widely used worldwide comprises three important elements: muscle mass, muscle strength, and physical performance[16]. Past research on sarcopenia in the elderly has often focused on muscle mass[17]. After 10 years of research, the EWGSOP has identified decreased muscle strength as a key feature of sarcopenia and muscle function as an indicator of severe sarcopenia[18]. In addition, muscle strength and function are recognized as being more predictive of adverse outcomes in older adults than muscle mass.

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Considering that our data clearly linked parameters of physical performance to depression, we speculate that exercise interventions for muscle strength and function may lead to improvement of depressive mood. Researchers began to study the relationship between motion and emotion in the early 1990s [19], and recent evidence has shown that exercise but not nutritional support may be beneficial in patients with depression[20]. Andrea et al. reported that the remission rate was 47% in a high-intensity exercise group and 30% in a low-intensity exercise group after 12 weeks of intervention, while that of the control group was 29%[21]. These researchers also observed no significant difference between exercise three times a week and five times a week. Hence, these results suggest that exercise intensity, not frequency, has a beneficial role in depression treatment. In addition, no clear side effects of exercise therapy have been reported, and there are no withdrawal symptoms, unlike the weight gain, dry mouth, and insomnia that may occur after withdrawal of drug therapy.

Furthermore, there are some links between sarcopenia and depressive mood[22]. First, they seem to share several common risk factors, such as upregulation of inflammatory factors[23]. Second, muscle is not only a motor organ, but also an effective, metabolically active endocrine organ. For example, skeletal muscle cells are highly abundant and myokine signaling has also been linked to brain neurogenesis and cognitive functions[24]. Leandro et al. revealed that there are possible therapeutic avenues for the treatment of depression that would involve targeting the PGC-1a 1-PPAR axis in skeletal muscle, without the need to cross the blood-brain barrier[25].

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Previous studies on the effects of the components of sarcopenia on depression have found sex differences. For example, in a recent study involving Japanese adults, decreased muscle mass (sarcopenia) was related to depression in older male patients with diabetes, but not in older females[9]. Contrary to these previous studies, our data indicated that depressive mood was inversely associated with chair stand test performance, gait speed and standing balance test performance in both men and women. This difference in results might be explained by the inclusion of relatively "young" old subjects (the average age was no more than 70), by the low severity of depression, or the small sample size in our study.

We also examined the relationship between the components of sarcopenia and blood sugar and lipid levels. In the multiple linear regression models, physical function was negatively associated with the level of glucose, whereas lipid metabolism did not show any association with the components of sarcopenia. This negative relationship between blood glucose and HbA1c levels and sarcopenia parameters was recently reported in other studies[26 27]. However, although basic research revealed and association between high-fat diet-induced muscle loss in aged rats and greater deposits of long-chain fatty acids[28], the exact relationship between lipids and sarcopenia needs to be determined in a further study.

There were certain limitations to this study. For example, it would have been improved if we had acquired data on activity levels and dietary habits. Second, a cross-sectional study cannot establish a causal relationship between depressive mood and sarcopenia, and future prospective studies will be needed to address this gap. Finally, our study sample was small; a larger sample would allow direct comparisons of subjects with

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similar levels of depressive mood, which would generate findings with greater applicability.

In conclusion, our study demonstrated that depressive mood was inversely associated with physical function in terms of gait speed, standing balance test performance, and strength of leg muscles, but not with muscle mass. Together, our findings highlight the significance of muscle function in relation to mental health, and suggest that exercise-enhanced muscle function may be an effective intervention for depression.

Author contributions

LC performed the statistical analysis and wrote the manuscript. TT conducted handgrip strength and physical function assessments. YS conducted the DXA. HQ did the biochemical tests to measure levels of blood glucose and lipids. SL designed the experiments and revised the manuscript. All authors gave final approval of the version to be published.

Conflict of interest

The authors declare that they have no conflict of interest.

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Table 1. Anthropometrics, muscle strength and mass, and physical performance of study participants.

Parameter	Male	Female
n	101	149
Age (year)	69.82 ± 6.84	67.69 ± 6.20
Height (cm)	168 ± 5.79	155 ± 5.72
Weight (kg)	69.22 ± 9.10	58.42 ± 8.60
BMI (kg/m2)	24.42 ± 2.77	24.09 ± 3.11
Muscle Strength		
Handgrip Strength	38.86 ± 7.89	24.48 ±4.38
Chair Stand Test	9.18 ± 3.18	9.47 ± 5.56
Muscle Mass		
ASM (kg)	20.16 ± 2.73	13.65 ± 2.02
SMI (kg/m^2)	7.10 ± 0.79	5.63 ± 0.72
Physical Performance		
Gait speed (m/s)	1.27 ± 0.29	1.26 ± 0.24
Standing balance test (score)	3.80 ± 0.54	3.76 ± 0.64
SPPB (score)	11.36 ± 1.31	11.47 ± 1.16
MMSE (score)	27.68 ± 1.93	27.47 ± 2.17
Depression (score)	4.43 ± 3.53	4.62 ± 4.11
Glucose (mmol/L)	5.43 ± 1.07	5.60 ± 1.51
TG (mmol/L)	1.53 ± 0.84	1.73 ± 0.98
TC (mmol/L)	4.48 ± 0.91	4.97 ± 1.03
HDL-C (mmol/L)	1.13 ± 0.30	1.73 ± 0.98
LDL-C (mmol/L)	2.56 ± 0.73	2.75 ± 0.90

Variables are expressed as mean ± SD; BMI, body mass index; ASM, appendicular skeletal muscle mass; SMI, appendicular skeletal muscle mass index; SPPB, Short Physical Performance Battery; TG, triglyceride; TC, cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; MMSE, mini-mental status examination.

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Table 2. Multiple linear regression analyses of the effects of muscle mass, muscle strength and physical function on depression.

	SMI		Handgrip Strength		Chair Stand Test		Gait speed		Standing Balance Test		SPPB	
	β	*p*	***β***	*p*	***β***	*p*	***β***	*p*	***β***	*p*	***β***	*p*
Age	-0.006	0.366	-0.22	*****0.001**	0.08	0.132	-0.009	****0.002**	-0.019	****0.002**	-0.031	***0.011**
Sex	-1.485	*****<0.001**	-14.963	*****<0.001**	0.285	0.685	-0.05	0.184	-0.075	0.36	0.059	0.713
BMI	0.157	*****<0.001**	0.233	0.118	0.176	0.147	-0.008	0.217	-0.012	0.388	-0.044	0.111
Glucose(mmol/L)	-0.003	0.928	-0.338	0.275	0.307	0.222	-0.034	***0.012**	-0.083	****0.005**	-0.153	****0.008**
TG (mmol/L)	0.05	0.412	0.562	0.333	0.235	0.618	-0.018	0.482	0.073	0.184	-0.018	0.868
TC (mmol/L)	0.023	0.845	1.372	0.212	0.438	0.623	0.08	0.097	-0.047	0.655	-0.057	0.778
HDL-C (mmol/L)	0.173	0.291	-0.059	0.969	1.624	0.197	-0.127	0.062	-0.224	0.129	-0.509	0.078
LDL-C (mmol/L)	-0.028	0.821	-2.008	0.081	-1.366	0.144	-0.07	0.131	0.063	0.563	0.263	0.217
Depression Score	0.004	0.684	-0.174	0.092	0.325	*****<0.001**	-0.009	***0.041**	-0.24	***0.016**	-0.061	****0.002**

Adjustment for age, gender and BMI; β standardized coefficient

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ indicates a statistically significant difference

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Fig. 1 Pearson's correlation between SMI and Depression Score in Male. (A) and Female(B).

SMI: appendicular skeletal muscle mass index

Fig. 2 The strength of the upper and lower limbs in relation to Depression Score. (A, C) Handgrip strength and Depression Score. (B, D) Chair stand test and Depression Score.

$P < 0.05$ indicates statistically significant difference

Fig. 3 Pearson's correlation between Physical Performance and Depression Score in Male or Female. (A, D) Gait speed correction with Depression Score. (B, E) Standing balance test correction with Depression Score. (C, F) SPPB correction with Depression Score.

$P < 0.05$ indicates statistically significant difference

Fig. 4 Depression Score in different stages of sarcopenia.

Normal: n=118 Pre-sarcopenia: n=91 Sarcopenia: n=40

$P < 0.05$ indicates statistically significant difference

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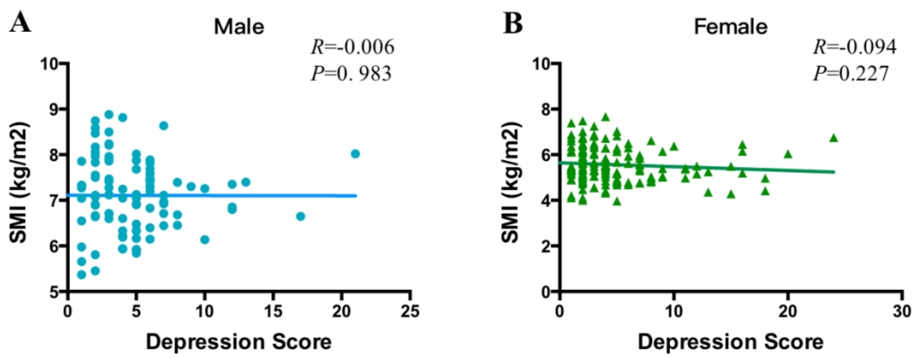

Fig. 1 Pearson's correlation between SMI and Depression Score in Male. (A) and Female(B).

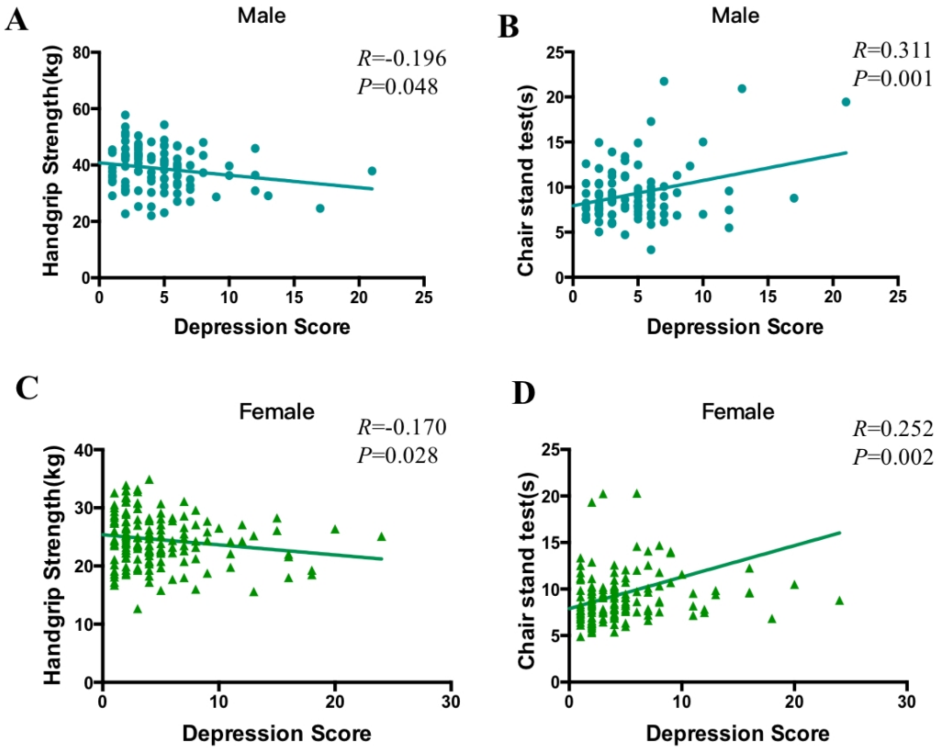

Fig. 2 The strength of the upper and lower limbs in relation to Depression Score. (A, C) Handgrip strength and Depression Score. (B, D) Chair stand test and Depression Score.

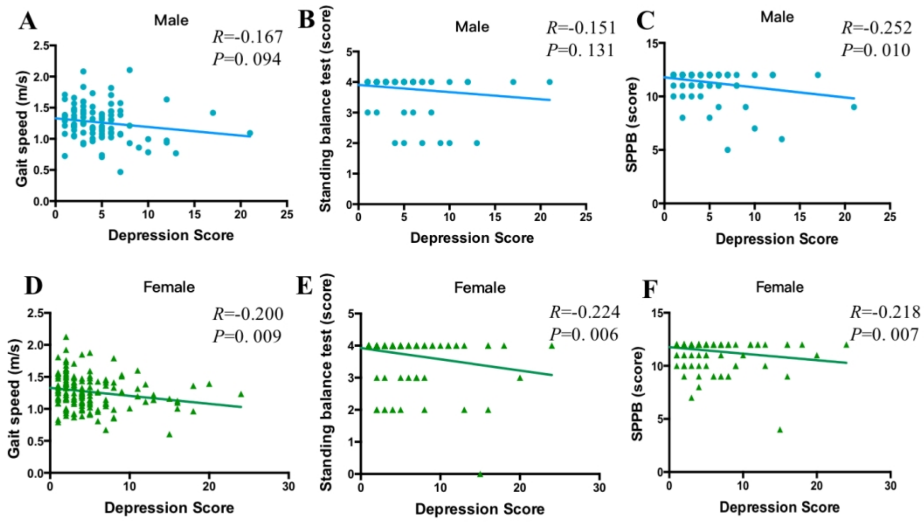

Fig. 3 Pearson's correlation between Physical Performance and Depression Score in Male or Female. (A, D) Gait speed correction with Depression Score. (B, E) Standing balance test correction with Depression Score. (C, F) SPPB correction with Depression Score.

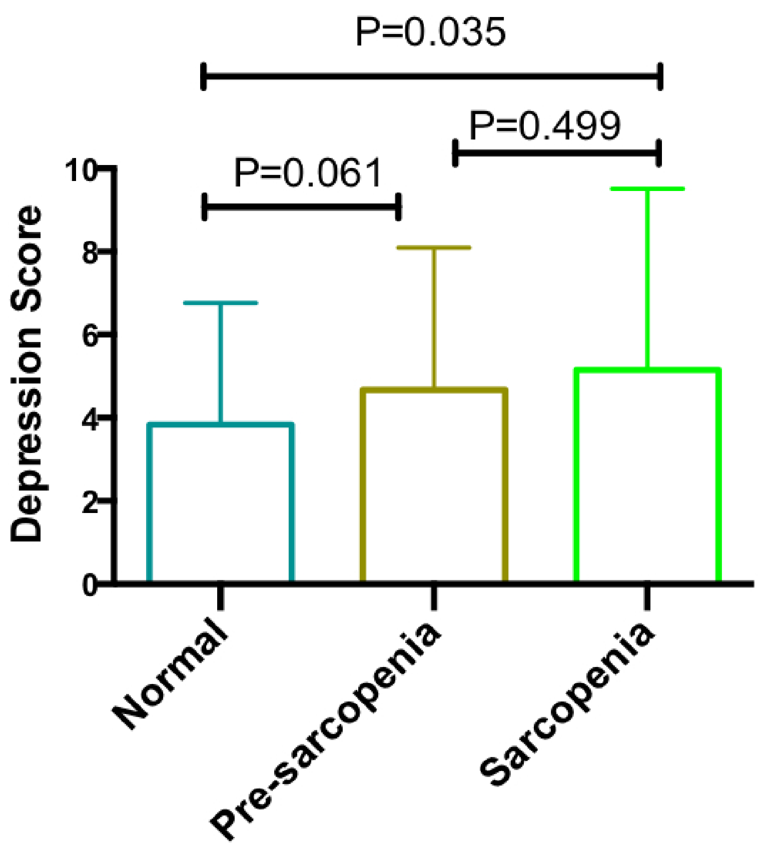

Fig. 4 Depression Score in different stages of sarcopenia.
Normal: n=118 Pre-sarcopenia: n=91 Sarcopenia: n=40

BMJ Open

The correlation of sarcopenia and depressive mood in older community dwellers: a cross-sectional observational study in china

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-038089.R1
Article Type:	Original research
Date Submitted by the Author:	12-May-2020
Complete List of Authors:	chen, lei; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital sheng, yunlu; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital qi, hanmei; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital tang, tingting; the First People's Hospital of Yancheng, Department of Geratology yu, jing; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital lv, shan; Jiangsu Province People's Hospital and Nanjing Medical University First Affiliated Hospital,
Primary Subject Heading:	Geriatric medicine
Secondary Subject Heading:	Mental health, Public health
Keywords:	Depression & mood disorders < PSYCHIATRY, GERIATRIC MEDICINE, Old age psychiatry < PSYCHIATRY

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The correlation of sarcopenia and depressive mood in older community dwellers: a cross-sectional observational study in china

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Funding

This study was funded by a grant from the National Natural Science Foundation of China (81871096) to Shan Lv.

Word count: 2854

Tables: 2

Figures: 4

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Abstract

Objective: Whether sarcopenia is detrimental to depression is still controversial, which may be due to the three components of the sarcopenia. Our objective was to define the correlation between depression and sarcopenia in older Chinese community dwellers.

Design: The study has a cross-sectional design.

Setting: The study was conducted in Jiangsu, China.

Participants: A total of 101 men and 149 women aged 60 years or older were recruited.

Outcome measures: Lean tissue mass was measured by dual-energy X-ray absorptiometry. Muscle strength in the upper and lower limbs was measured by a handheld dynamometer and a chair stand test, respectively. Physical performance was assessed by gait speed and standing balance tests. Depressive mood was assessed using the Geriatric Depression Scale-30 (range 0-30).

Results: Participants in the sarcopenia group had a higher mean depression score than the normal group(p=0.002). Pearson's correlation analysis showed that depression was negatively associated with muscle strength (handgrip strength: R = -0.170, p = 0.028 for women, R = -0.196, p = 0.048 for men; chair stand test performance: R = 0.252, p = 0.002 for women, R = 0.311, p = 0.001 for men) and physical performance(gait speed: R = -0.200, p = 0.009, standing balance test performance: R= -0.224, p= 0.006, SPPB: R = -0.218, p = 0.007 for women; SPPB: R = -0.252, p= 0.01 for men). Multiple linear regression models revealed that depressive mood was inversely associated with chair stand test(β=0.325, p<0.001), gait speed(β=-0.009, p=0.041) and standing balance test (β=-0.24, p=0.016) after adjusting for confounding factors, while no significant correlation was observed between depressive mood and muscle mass.

Conclusion: The diagnostic components of sarcopenia—strength of the leg muscles (chair stand test) and physical performance (gait speed and standing balance test)—were associated with depressive mood.

Keywords: Muscle mass, Muscle strength, Physical performance, Depression, Older adults

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Strengths and limitations of this study

- Our findings highlight the significance of muscle strength and function but not muscle mass in relation to depression in older Chinese community dwellers.
- It would have been improved if we had acquired data on activity levels and dietary habits.
- A cross-sectional study can not establish a causal relationship between depressive mood and sarcopenia.
- Since the enrolled participants were relatively healthy, it is necessary to recruit more participants with large variability in parameters to avoid selection bias.
- Another limitation was the lack of the interventions and follow-up due to their time-consuming nature as well as the poor compliance of participants.

Introduction

Over the last few decades, with the aging of the global population, sarcopenia has risen to be an important public health problem. As we all known, skeletal muscle comprises approximately 40% of the total body mass in a healthy-weight individual[1]. Sarcopenia is defined as the loss of muscle mass, muscle strength and decreased physical performance due to aging[2]. Therefore, sarcopenia is a potential risk factor for frailty, fall, disability, delayed wound healing, diabetes, cardiovascular disease and so on in older adults[3]. At present, methods of delaying sarcopenia constitute a hot topic in the field of geriatric medicine, and physical exercise is one of the most effective ways to maintain and gain muscle mass and strength[4].

Depression is characterized by significant and lasting sadness, and is the most common type of mood disorder. Clinically, a patient's level of depression can range from

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extreme grief to feelings of inferiority, pessimism, world-weariness, and serious suicidal behavior[5]. It is generally accepted that depression is a leading cause of disability worldwide and a major contributor to the overall global burden of disease[6]. An article published in 2017 on the official website of the World Health Organization (WHO) reported that 322 million people suffered from depression worldwide, and that the number of patients increased by 18.4% between 2005 and 2015. China is the country with the largest number of people suffering from depressive disorders, with a prevalence of 4.2%[7]. However, compared with other psychiatric patients, patients with depression have poor treatment compliance, and they often refuse any treatment due to their shame regarding the condition. Exercise can not only improve the mood of patients with depression, but also promote the recovery of social function and reduce shame. To date, the strongest evidence for the benefits of physical activity in depression comes from randomized controlled trials, which report that exercise intervention using a physical activity program had positive effects on depressive status[8]. In addition, several large prospective cohort studies have indicated an inverse relationship between physical activity and depressive symtoms[9 10].

Given that physical exercise can not only delay sarcopenia but also treat depression, and muscle tissue is the largest exercise and endocrine metabolism organ, a number of studies have investigated the relationship between sarcopenia and depressive mood[11]. For example, a cross-sectional sample of a longitudinal cohort from the Ansan Geriatric (AGE) Study reported that depression in elderly Koreans was associated with low body mass and sarcopenia, especially in men[12]. In addition, a statistically significant

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relationship was observed between sarcopenia and depression in older male patients with diabetes[13]. A recent study involving Japanese urban-dwelling older adults revealed that depressive mood was not associated with decreased muscle mass, but was associated with low muscle strength and low physical performance[14]. In contrast, results from the 2010–2011 Korean National Health and Nutrition Examination Survey showed that sarcopenia was not associated with depression in Korean adults[15]. Therefore, the exact relationship between depressive mood and the components of sarcopenia is still unknown.

In this study, we chose healthy community dwellers aged 60 years or older who did not suffer from diseases that might affect muscle metabolism. Our aim was to explore the correlation between depressive mood and the diagnostic components of sarcopenia in older Chinese community dwellers.

Materials and methods

Study participants

The study participants were selected from older community dwellers who participated in the annual health screening program at Huaqiao Road Community Health Service Center in Jiangsu, China. The inclusion criterion was an age of 60 years or older. Participants were excluded if they had diseases that might affect muscle metabolism such as inflammatory myopathy, Parkinson's disease, stroke, myocardial infarction, significant liver disease, a creatinine clearance of <30 ml/min or cancer. The mental status of the study participants was assessed by the Mini-Mental Status Examination (MMSE)

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and participants with cognitive impairment were excluded. Participants who failed to go through the assessment of sarcopenia were also excluded. Finally, 101 men and 149 women were recruited for the study.

Height and weight were measured by standard methods with participants wearing light clothing without shoes. Body mass index (BMI) was calculated as BMI (kg/m^2) = Weight (kg)/height^2 (m^2).

Ethical and legal considerations

The clinical study was approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University, Jiangsu, China, in accordance with the Declaration of Helsinki. The participants themselves gave their written informed consent to participate in the study and were informed that they could refuse to participate at any stage.

Muscle mass, muscle strength and physical performance assessment

A dual-energy X-ray absorptiometry (DXA) scanner (Hologic Inc., Bedford, MA, USA) was used to measure appendicular skeletal muscle mass (ASM). As absolute muscle mass correlates with height, the appendicular skeletal muscle mass index (SMI) was calculated as SMI (kg/m^2) = ASM (kg)/height^2 (m^2). All scans were obtained by the same certified technician. The instruments used in this study exhibited stable long-term performance [coefficient of variation (CV) < 0.5%] and satisfactory in vivo precision.

The grip strength of each participant's dominant hand was measured three times with a hand dynamometer (Jamar®, Los Angeles, CA, USA). Three attempts separated by a 1-min interval were recorded, and the maximum value (in kg) was recorded for further

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analysis. The chair-stand test, also called the chair-rise test, can be used as a proxy to assess the strength of the leg muscles (quadriceps muscle group). The participants were required to rise five times from a seated position as fast as possible without using his or her arms. The time was recorded manually with a stopwatch.

Physical performance was assessed by gait speed and the standing balance test[16]. For the gait speed, participants were asked to walk along a straight walkway on a flat floor at their usual speed without deceleration. They walked over a 4 m distance between markers placed at 3 m and 7 m from the start of the walkway. The time was measured manually with a stopwatch，and then the mean walking speed (m/s) was calculated. The test was performed twice, with the faster of the two walks used for analysis. For the standing balance test, participants were asked to stand in three positions (with feet together, with the inside of the heel of the front foot close to the big toe of the rear foot, and with one foot forward and one backward), using arms or other means to maintain balance without moving the feet.

The Short Physical Performance Battery (SPPB) comprises the measurements of gait speed, standing balance, and the chair-stand test. The maximum individual test score is 4 and the maximum total SPPB score is 12.

Depression Assessment

The severity of depressive mood was evaluated using the 30-item Geriatric Depression Scale (GDS-30) developed by Brank et al. in 1982. The GDS-30 was rater-administered in a standardized manner with the interviewer questioning the subjects and recording their responses to the individual items.

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All items in the GDS-30 are rated as 0 or 1; specifically, 1 = "No" and 0 = "Yes" for some items (1, 5, 7, 9, 15, 19, 21, 27, 29, 30) but 0 = "Yes" and 1 = "No" for the remaining items. Item scores are summed, resulting in a possible total score of 0-30. High scores represent more severe depression.

Diagnosis of Sarcopenia

According to the Asian Working Group for Sarcopenia (AWGS) criteria in Older People[17], sarcopenia is defined according to muscle mass, muscle strength, and physical performance. Possible sarcopenia is determined by low muscle strength or low physical performance (5-repeat chair stand test≥12s). Sarcopenia is defined as low muscle mass plus either diminished muscle strength or low physical performance.

Low muscle mass was defined as an SMI below 7.0 kg/m^2 for men and 5.4 kg/m^2 for women. Low muscle strength was defined as handgrip strength < 28 kg for men and < 18 kg for women. Low physical performance was defined as gait speed<1.0m/s or an SPPB score ≤ 9.

Statistical analysis

Descriptive data are presented as the means ± standard deviations (SDs) or medians (first to third quartile). The associations between depression score and muscle mass, muscle strength, and physical performance were examined using Pearson's correlation analysis. Multiple linear regression models were used to analyze SMI, handgrip strength, the chair-stand test, gait speed, and the SPPB score using age, gender, and BMI data as

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confounding variables. All statistical analyses were performed using SPSS version 20.0 (IBM Corp, Armonk, NY, USA), and $p < 0.05$ was considered statistically significant.

Patient and public involvement

No patient was involved in developing the research questions, outcome measurements or design of the study. We are unable to disseminate the findings of the research directly to the study participants.

Results

General characteristics, muscle mass, muscle strength and function and depressive mood of participants

Table 1 shows the participants' demographic characteristics. The analysis included data from 250 older Chinese community dwellers, of whom 149 were men (mean age: 69.82 ± 6.84 years) and 101 were women (mean age: 67.69 ± 6.20 years). The mean GDS-30 scores in the male and female groups were 4.43 ± 3.53 and 4.62 ± 4.11 points, respectively. The mean relative muscle mass (SMI) was 7.10 ± 0.79 kg/m^2 for men and 5.63 ± 0.72 kg/m^2 for women. We evaluated the strength of the upper and lower limbs by the handgrip strength test (38.86 ± 7.89 kg for men, 24.48 ± 4.38 kg for women) and the chair stand test (9.18 ± 3.18 s for men, 9.47 ± 5.56 s for women), respectively. The assessment of physical performance involved the measurement of gait speed, the standing balance test, and the SPPB score.

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Correlation between depressive mood and muscle mass, muscle strength, and physical performance

We carried out a Pearson correlation analysis of the above data, and no significant correlation was observed between muscle mass and depressive mood in either men or women (Fig. 1). Then we found that depression scores correlated significantly with muscle strength in both sexes, in terms of handgrip strength (R = -0.196, p = 0.048 for men, R = -0.170, p = 0.028 for women) and chair stand test performance (R = 0.311, p = 0.001 for men, R = 0.252, p = 0.002 for women) (Fig. 2). Moreover, as shown in Fig 3, in women, depression was negatively associated with physical performance measured by gait speed (R = -0.200, p = 0.009), standing balance test performance (R = -0.224, p = 0.006), and SPPB score (R = -0.218, p = 0.007). There was also a negative correlation between depressive mood and the SPPB score in men(R = -0.252, p = 0.010) but not gait speed or standing-balance test performance.

Multiple regression analysis of depressive mood, muscle mass, muscle strength, and physical function

Given the significant independent relationships between age, sex, BMI, glucose, lipid metabolism, and parameters of sarcopenia, we performed multiple linear regression analyses. In our multiple linear regression models (Table 2), depressive mood was inversely associated with chair stand test(β=0.325, p<0.001), gait speed(β=-0.009, p=0.041), standing balance test scores(β=-0.24, p=0.016)and SPPB scores(β=-0.061,

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p=0.002), while no significant correlation was found between depressive mood and muscle mass.

Depression scores in different stages of sarcopenia

We further analyzed the depression scores of subjects exhibiting different stages of sarcopenia, such as possible-sarcopenia and sarcopenia. Following the AWGS criteria, the numbers of participants in normal, possible-sarcopenia, and sarcopenia groups were 121, 74 and 55, respectively. As expected, the participants' depression scores gradually increased with the extent of muscle loss. Participants with sarcopenia had higher depression scores than the normal group (p = 0.002), while there was no significant difference between the depression scores of the possible-sarcopenia and sarcopenia groups (Fig. 4).

Discussion

Overall, our data revealed an association between depressive mood and sarcopenia in adults aged 60 and over. This was consistent with the results of a meta-analysis, whose authors concluded that patients with sarcopenia were likely to present with depression[18]. Furthermore, we found that depressive mood was negatively associated with the strength of leg muscles and physical performance measured by gait speed and the standing balance and SPPB scores, even after adjusting for confounding factors. However, no significant correlation was observed between muscle mass and depressive mood in either men or women.

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Although depression is not an inevitable result of aging, depressive diseases of the older population are a common and serious health problem that are related to coexisting diseases, functional impairment, excessive use of health care resources and increased mortality (including suicide). The incidence of depression in the older individuals living in the community is between 2% to approximately 10%. The incidence of depression is higher in the older adults with coexisting medical diseases and in those in comprehensive medical institutions. The prevalence of depression in the older adults in hospitals is more than 30%[19]. Thus, early detection of depression-related risk factors and early intervention are particularly important in the context of a single course of antidepressant treatment in the face of poor patient compliance.

The definition of sarcopenia widely used worldwide comprises three important elements: muscle mass, muscle strength, and physical performance[20]. Past studies on sarcopenia in old adults have often focused on muscle mass[21]. After 10 years of research, the EWGSOP2 has identified decreased muscle strength as a key feature of sarcopenia and muscle function as an indicator of severe sarcopenia[22]. In addition, muscle strength and function are recognized as being more predictive of adverse outcomes in older adults than muscle mass.

Considering that our data clearly linked parameters of physical performance to depression, we speculate that exercise interventions for muscle strength and function may lead to improvement in depressive mood. Researchers began to study the relationship between motion and emotion in the early 1990s[23], and recent evidence has shown that exercise but not nutritional support may be beneficial in patients with depression[24].

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Andrea et al. reported that the remission rate was 47% in a high-intensity exercise group and 30% in a low-intensity exercise group after 12 weeks of intervention, while that of the control group was 29%[8]. These researchers also observed no significant difference between exercise three times a week and five times a week. Hence, these results suggest that exercise intensity, not frequency, has a beneficial role in depression treatment. In addition, no clear side effects of exercise therapy have been reported, and there are no withdrawal symptoms, unlike the weight gain, dry mouth, and insomnia that may occur after withdrawal from drug therapy.

Furthermore, there are some links between sarcopenia and depressive mood[25]. First, they seem to share several common risk factors, such as upregulation of inflammatory factors[26]. Second, muscle is not only a motor organ, but also an effective, metabolically active endocrine organ. For example, skeletal muscle cells are highly abundant and myokine signaling has also been linked to brain neurogenesis and cognitive functions[27]. Leandro et al. revealed that there are possible therapeutic avenues for the treatment of depression that would involve targeting the PGC-1a 1-PPAR axis in skeletal muscle, without the need to cross the blood-brain barrier[28].

Previous studies on the effects of the components of sarcopenia on depression have found sex differences. For example, in a recent study involving Japanese adults, decreased muscle mass (sarcopenia) was related to depression in older men with diabetes, but not in older women[13]. Contrary to these previous studies, our data indicated that depressive mood was inversely associated with chair stand test performance, gait speed and standing balance test performance in both men and women. This difference in results

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might be explained by the inclusion of relatively "young" older subjects (the average age was no more than 70), by the low severity of the reported depression, or the small sample size in our study.

There were certain limitations to this study. For example, since better physical function is associated with improvement of sarcopenia and a lower incidence of depressive symptoms, we believe that being able to add physical activity is beneficial to analyze the risk factors for depression and sarcopenia. We will acquire data on activity levels, such as with the International Physical Activity Questionnaire (IPAQ), in future studies. Second, the mean SPPB scores of men/women in the study were 11.36/11.47, which means that the enrolled participants were relatively healthy. It is necessary to recruit more participants with large variability in their parameters to avoid selection bias. Third, a cross-sectional study cannot establish a causal relationship between depressive mood and sarcopenia, and future prospective studies will be needed to address this gap. Fourth, another limitation was the lack of the interventions and follow-up due to their time-consuming nature as well as the poor compliance of participants. Finally, our study sample was small; a larger sample would allow direct comparisons of subjects with similar levels of depressive mood, which would generate findings with greater applicability. These shortcomings merit further study.

In conclusion, our study demonstrated that depressive mood was inversely associated with physical function in terms of gait speed, standing balance test performance, and strength of leg muscles, but not with muscle mass. Together, our findings highlight the

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significance of muscle function in relation to mental health, and suggest that exercise-enhanced muscle function may be an effective intervention for depression.

Author contributions

LC wrote the manuscript. HQ conducted handgrip strength and physical function assessments. YS conducted the DXA. TT performed the statistical analysis. JY did depression assessment for all participants. SL designed the experiments and revised the manuscript. All authors gave final approval of the version to be published.

Conflict of interest

The authors declare that they have no conflict of interest.

Data sharing statement

No additional data are available.

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Table 1. Anthropometrics, muscle mass, muscle strength, and physical performance of the participants.

Parameter	Men	Women
n	101	149
Age (year)	69.82 ± 6.84	67.69 ± 6.20
Height (cm)	168 ± 5.79	155 ± 5.72
Weight (kg)	69.22 ± 9.10	58.42 ± 8.60
BMI (kg/m2)	24.42 ± 2.77	24.09 ± 3.11
Muscle Strength		
Handgrip Strength	38.86 ± 7.89	24.48 ±4.38
Chair Stand Test	9.18 ± 3.18	9.47 ± 5.56
Muscle Mass		
ASM (kg)	20.16 ± 2.73	13.65 ± 2.02
SMI (kg/m^2)	7.10 ± 0.79	5.63 ± 0.72
Physical Performance		
Gait speed (m/s)	1.27 ± 0.29	1.26 ± 0.24
Standing balance test (score)	3.80 ± 0.54	3.76 ± 0.64
SPPB (score)	11.36 ± 1.31	11.47 ± 1.16
MMSE (score)	27.68 ± 1.93	27.47 ± 2.17
Depression (score)	4.43 ± 3.53	4.62 ± 4.11

Variables are expressed as mean ± SD; BMI, body mass index; ASM, appendicular skeletal muscle mass; SMI, appendicular skeletal muscle mass index; SPPB, Short Physical Performance Battery; MMSE, mini-mental status examination.

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Table 2. Multiple linear regression analyses of the effects of muscle mass, muscle strength and physical function on depression.

	SMI		Handgrip Strength		Chair Stand Test		Gait speed		Standing Balance Test		SPPB	
	β	*p*	***β***	*p*	***β***	*p*	***β***	*p*	***β***	*p*	***β***	*p*
Age	-0.006	0.366	-0.22	***0.001**	0.08	0.132	-0.009	****0.002**	-0.019	****0.002**	-0.031	***0.011**
Gender	-1.485	*****<0.001**	-14.963	*****<0.001**	0.285	0.685	-0.05	0.184	-0.075	0.36	0.059	0.713
BMI	0.157	*****<0.001**	0.233	0.118	0.176	0.147	-0.008	0.217	-0.012	0.388	-0.044	0.111
Depression Score	0.004	0.684	-0.174	0.092	0.325	*****<0.001**	-0.009	***0.041**	-0.24	***0.016**	-0.061	****0.002**

Adjustment for age, gender and BMI; β standardized coefficient

*p < 0.05; **p < 0.01; ***p < 0.001 indicates a statistically significant difference

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Fig. 1 Pearson's correlation between SMI and the depression score in men(A) and women(B).

SMI: appendicular skeletal muscle mass index

Fig. 2 The strength of the upper and lower limbs in relation to the depression score. (A, C) Handgrip strength and depression score. (B, D) Chair stand test and depression score.

$p < 0.05$ indicates a statistically significant difference

Fig. 3 Pearson's correlation between physical performance and depression score in men or women. (A, D) Gait speed correlation with depression score. (B, E) Standing balance test correlation with depression score. (C, F) SPPB correlation with depression score.

$p < 0.05$ indicates a statistically significant difference

Fig. 4 Depression score in different stages of sarcopenia.

Normal: n=121 Possible-sarcopenia: n=74 Sarcopenia: n=55

$p < 0.05$ indicates a statistically significant difference

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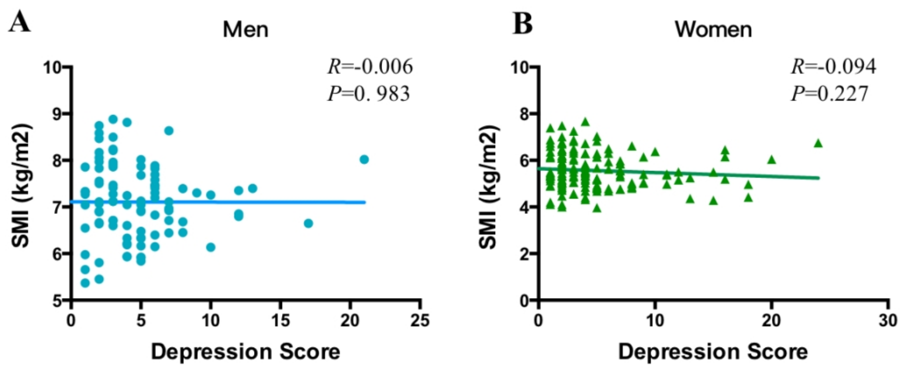

Fig. 1 Pearson's correlation between SMI and the depression score in men(A) and women(B).

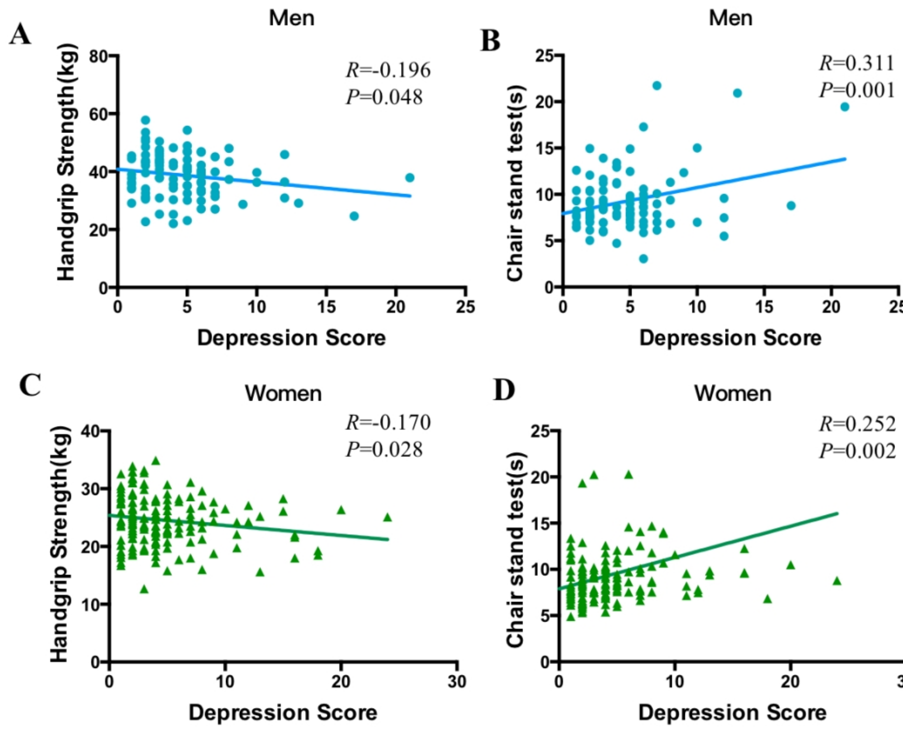

Fig. 2 The strength of the upper and lower limbs in relation to the depression score. (A, C) Handgrip strength and depression score. (B, D) Chair stand test and depression score.

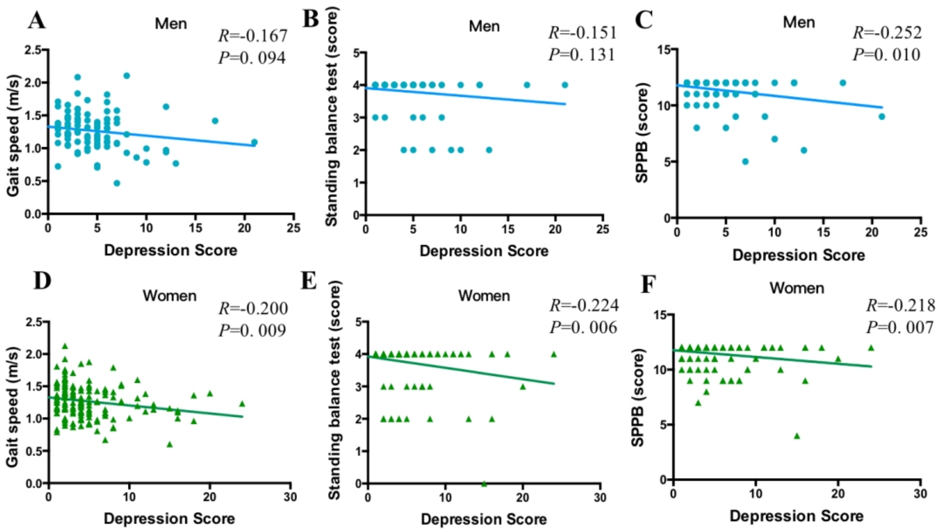

Fig. 3 Pearson's correlation between physical performance and depression score in men or women. (A, D) Gait speed correlation with depression score. (B, E) Standing balance test correlation with depression score. (C, F) SPPB correlation with depression score.

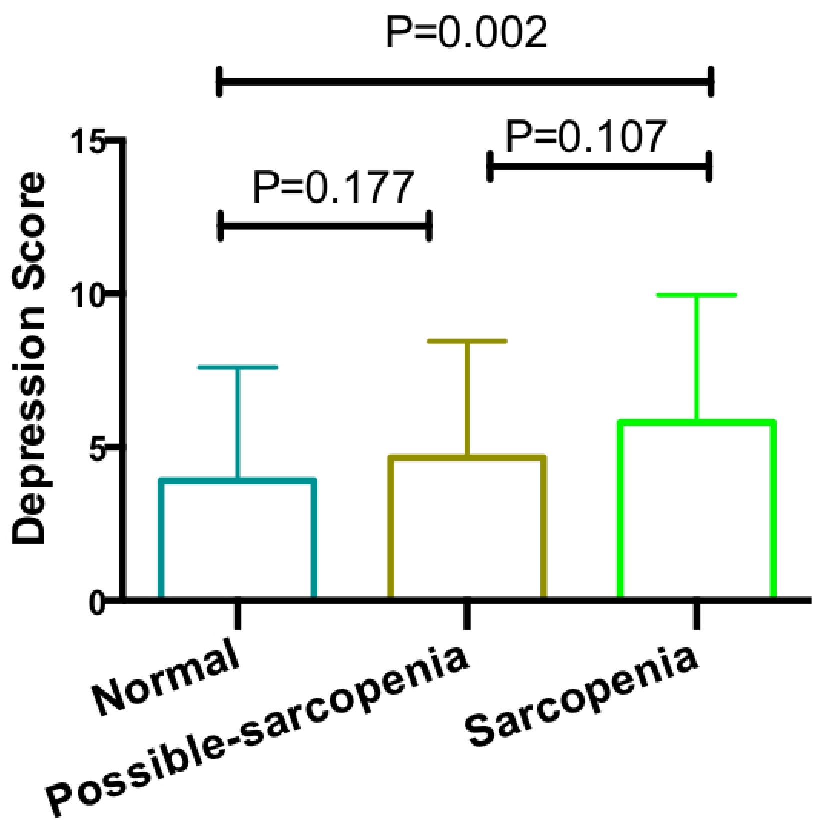

Fig. 4 Depression score in different stages of sarcopenia.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1，2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3，4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5，6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6，7，8
Bias	9	Describe any efforts to address potential sources of bias	*8*
Study size	10	Explain how the study size was arrived at	5，6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8，9
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	10，11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9，10，11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12，13，14，15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14，15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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